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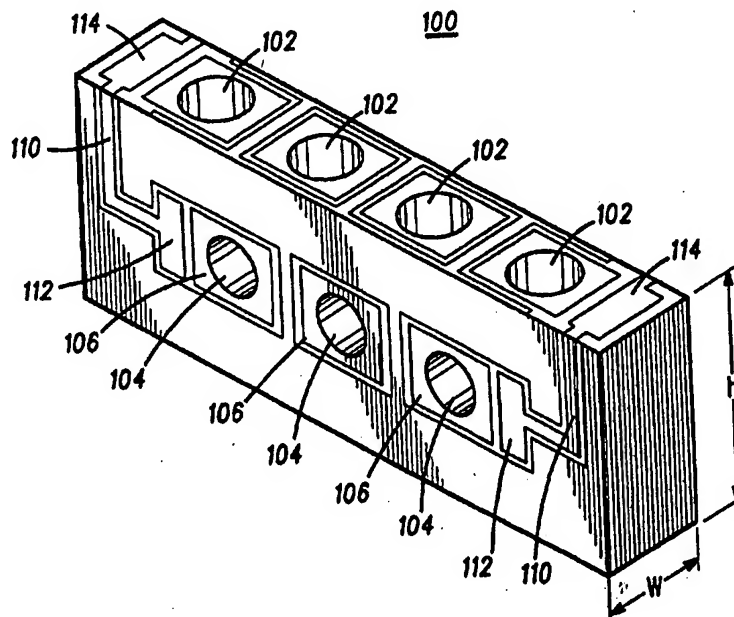
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: MULTI-FREQUENCY CERAMIC BLOCK FILTER WITH RESONATORS IN DIFFERENT PLANES

## (57) Abstract

A ceramic filter (100) is disclosed. The filter (100) has a filter body comprising a dielectric material having a plurality of surfaces with each surface having a plurality of metallized through holes extending through the dielectric material defining a first series of resonators (102) in a first plane and a plurality of second metallized through holes in a different plane and extending transversely with relation to the first, defining a second series of resonators (104). The filter (100) also has a metallization layer substantially coating all surfaces of the filter (100) with the exception that a portion of the surface surrounding each resonator is left unmetallized, and a coupling structure (108) for coupling electrical signals into and out of filter (100).



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# MULTI-FREQUENCY CERAMIC BLOCK FILTER WITH RESONATORS IN DIFFERENT PLANES

## 5 Field of the Invention

This invention relates to electrical filters, and more particularly, to ceramic block filters with resonators in different planes.

## 10 Background of the Invention

The use of dielectric block filters to remove undesirable electrical frequencies from an electrical  
15 signal is well known in the art.

Ceramic block filters have found wide acceptance for use in radio communications devices, particularly high frequency devices such as pagers, cellular telephones, and other telecommunications devices.

20 The blocks are relatively easy to manufacture, rugged, have improved performance characteristics over discrete lumped circuit elements, and are relatively compact.

Although various improvements have been made in  
25 the design of ceramic filters, many designs still incorporate metallized through holes to form resonators. The trend toward miniaturization of components which have lower losses and smaller sizes has been occurring gradually over the past several years.

30 Another trend in the industry involves the use of higher frequencies at higher bands in the electromagnetic spectrum for wireless telecommunications equipment. Whereas prior art filters were required to perform in the UHF field, some next generation wireless

telecommunications equipment will operate at much higher microwave frequencies.

The ability of any single communication device to retain its viability and utility will directly depend upon its capacity to communicate with other mediums of communication.

As a result, ceramic block filters must not only continue to reduce their size, cost and weight, but they must also evolve to simultaneously filter multiple bands in the electromagnetic spectrum.

A dielectric ceramic block which could filter two or more different pass-band frequencies in a single block while also reducing size by making a more efficient use of block space, would be considered an improvement over the prior art.

#### Brief Description of the Drawings

FIG. 1 shows a perspective view of a multi-frequency ceramic block filter achieved by placing resonators in different planes, in accordance with the present invention.

FIG. 2 shows a rear perspective view of the multi-frequency ceramic block filter of FIG. 1, in accordance with the present invention.

FIG. 3 shows an alternate multi-frequency ceramic block duplex filter with resonators in different planes located at each end of the block, in accordance with the present invention.

FIGS. 4A and 4B show rear and front views of a multi-frequency ceramic block dual duplex filter, in accordance with the present invention.

FIG. 5 shows a graph of a frequency response curve when two series of resonators are coupled to the same

input-output pads in accordance with the present invention.

FIG. 6 shows a typical frequency response curve for a Personal Communication Services (PCS) band, in accordance with the present invention.

### Detailed Description of the Preferred Embodiment

FIG. 1 shows a preferred embodiment of a multi-frequency ceramic block filter 100. The filter 100 has the ability to pass two distinct frequency bands due to the fact that there are resonators in two different planes of the filter block.

The relationship between the two passed frequency bands will depend upon the dimensions of the block itself. The ratios of the center frequencies will be approximately inversely proportional to the ratio of the length of the resonators, which will depend upon the dimensions of the block. As shown in FIGs. 1 and 2, a first series of vertical resonators 102 are located between the top and bottom surfaces of the block. They are generally slightly less than one-quarter wavelength at the center frequency of interest. A second set of horizontal resonators 104 are shown located between the front and rear surfaces of the dielectric block. Likewise, they are also slightly less than one-quarter wavelength at the desired center frequency of interest. Consequently, once the desired frequencies are known, the corresponding height and width parameter can be determined. More particularly, once the frequency of the filters are known, the block dimensions can then be set.

The aspect ratio, defined as the width to height ratio ( $w/h$  in FIG. 1), of most conventional ceramic block filters

tends to be rather large. This is due to the fact that filters are often designed to have very small height dimensions to accommodate the miniaturization requirements of many electronic products. The present invention actually exploits this characteristic of ceramic block filters by passing two very distinct and separate frequency bands.

In FIG. 1, the dielectric block is shown substantially coated on all surfaces with a metallization layer with the exception that a portion of the surface surrounding each resonator is unmetallized 106. The metallization layer may be applied using conventional screen printing and spraying processes.

An important feature in this design involves the relationship of the input-output pads to the various resonator planes. In the simplest case, if each series of resonators has its own corresponding set of input-output pads, then the result will merely be two separate and distinct filters which share the same dielectric block.

On the other hand, if both sets of resonators are coupled to the same set of input-output pads, then the result will be a single filter with two distinct passbands. An exemplary graph of a typical frequency response curve for this situation is shown in FIG. 5. FIG. 5 shows the graph of attenuation in decibels (dB) versus frequency. There are two distinct passbands centered at ( $f_{o1}$ ) and ( $f_{o2}$ ) respectively. The filter 100 as detailed above has two distinctive passbands, such as at about (cellular phone frequency) 860 MHz and (Iridium frequency) 1620 MHz, and offers distinct design advantages. A single ceramic filter which can be used for multiple frequencies offers the advantages of conserving size and weight while at the same time providing the feature of multi-frequency

filtering capabilities which is desirable in the electronics industry.

Referring to FIG. 2, a perspective view of the opposite (rear) side of the multi-frequency ceramic block of FIG. 1 is shown. When FIGs. 1 and 2 are viewed together, the vertical series of resonators 102 are capacitively coupled to the input-output pads 108 and the horizontal series of resonators 104 are capacitively coupled to a first pair of coupling members 112. The first pair of coupling members 112 are attached to conductive transmission lines 110 which run to the top surface of the block. On the top surface of the block, the transmission lines 110 attach to a second pair of coupling members 114. The second pair of coupling members 114 traverse the top surface of the block, provide additional capacitive coupling to the end resonators in the vertical plane, and connect to the input/output pads 108 which are located on the opposite surface of the filter, adjacent to the top surface of the block. Thus, items 110, 112, 114 and 108 define a wraparound input-output pad structure, to facilitate surface mounting.

Referring to FIG. 3, an alternate duplex filter 200 is shown. In this case, the dielectric block has three input-output pads, in which the first pad serves as an input for a Transmit (Tx) signal, the second pad serves as both an output pad for the Transmit (Tx) signal and an input pad for a Receive (Rx) signal, and a third pad serves as an output pad for a Receiving (Rx) signal as is illustrated in FIG. 3.

In FIG. 3, the duplex filter 200 has a first series of resonators in a horizontal plane and a second series of resonators in a vertical plane. In this embodiment, the two series of resonators are located at different ends of the block, as shown in FIG. 3. More particularly, at one end (distal end) of the block the resonators 202 are in the

vertical plane, and at the other end (proximal end) of the block the resonators 204 are in the horizontal plane. Once again, two separate and distinct filters are incorporated into one dielectric block to minimize space, weight and required componentry. As in FIG. 2, in FIG. 3 (although not shown) bottom and rear surfaces are metallized and the through holes adjacent to such surfaces define short circuited ends. The other end of the through-holes (resonators) are defined as the open-circuited ends.

10 In another embodiment, a dual duplexer is disclosed. In FIGs. 4A and 4B, resonators 402 and 404 form a pair of filters in the vertical plane. These filters combine to form a 3-part duplexer centered at a desired frequency (F1). The ceramic block becomes a dual duplexer when additional resonators 406 and 408 form a pair of filters in the horizontal plane. These filters combine to form a 2-part dual duplexer centered at a desired frequency (F2). Both duplexers share the same three input/output ports. In the dual duplexer design, two separate duplex filters can both be incorporated into the same dielectric ceramic block. As should be understood by those skilled in the art, various modifications can be made. Any filter which has resonators in different planes in the same dielectric block is considered within the scope of the present invention, as detailed herein.

25 Under current filter design, the coupling of the resonators can be controlled by non-symmetrical placement of the resonator holes. For example, by moving the location of the resonator holes closer to the input-output pads, capacitive coupling is increased. This would continue to be true with the present invention. However, due to the fact that resonators will be on sides of the block with larger surface areas, the designer has more



freedom to control coupling by strategic placement of the resonators.

From the above, it is clear that the resonators are not required to be centered on the surface of the block. In fact, movement of the resonator through holes to adjust the coupling between the resonators is a design parameter. Also, the present invention contemplates various resonator geometries. For example, one embodiment may use circularly shaped resonators whereas other embodiments may use elliptically shaped resonators. By adjusting the shape and spacing of the resonator through holes, many different filters can be designed. These parameters can also be used to adjust intercell coupling (K) and resonator impedance ( $Z_0$ ).

The present invention also allows a designer to take advantage of many different techniques for coupling the resonators to the input-output pads. For example, capacitively coupling through the dielectric, edge capacitance techniques, and the use of conductive transmission lines to facilitate capacitive coupling at another location on the block are just a few of the coupling techniques contemplated by the present invention. The coupling technique can become a major design consideration as the complexity of the multi-frequency block increases. Consequently, it may become necessary to employ different coupling techniques within the same dielectric block as dictated by design considerations. For example, a first series of resonators may be capacitively coupled to their respective input-output pads, whereas a second series of resonators may use conductive transmission lines in order to couple to the same input-output pads.

In one embodiment, the present invention can include a filter with resonator sets in three or more different

planes. For example, a triplex filter could be designed which has the capability of filtering three frequency bands. One set of resonators could filter a receive signal, another set of resonators could filter a transmit signal, and a third set of resonators could be used as a clean up filter, a local oscillator injection filter or the like. Thus, various front end filters in a cellular radio design can be integrated into a single dielectric block, thereby reducing the number of components while also reducing both size and weight.

In another embodiment, a transmit filter and a corresponding clean up filter can be incorporated into the same dielectric block. Since both filters would be operating at the same frequency, the result would be a dielectric block which has a cross-section which is essentially square in shape.

As the number of resonator sets is increased, the dielectric medium may evolve from a block form to other more elaborate shapes, for example, triangular or hexagonal in shape.

The present invention is particularly applicable for use in the Personal Communication Services (PCS) frequency bands and other wide passband filters. The fact that both PCS frequency bands are about 60 MHz wide with narrow guard bands can lead to difficulty in the design of duplex filters. However, by segmenting the PCS band (1850 MHz to 1910 MmHz) into two blocks (namely an upper block of 1880 MHz to 1910 MHz and a lower block of 1850 MHz to 1880 MHz), and by further aligning each set of resonators with a corresponding frequency, greater selectivity can be achieved.

FIG. 6 shows a typical frequency response curve for the PCS bands in accordance with the present invention. In FIG. 6, the dotted line shows typically wide passbands

with gently sloping frequency response curves achieved by conventional filter technology. In contrast, the two solid lines in each band (Tx & Rx) can be combined to attenuate the same signals. This is achieved by splitting each passband into two distinct segments and filtering each segment separately. This can be accomplished by placing a series of resonators in different planes of a ceramic block filter, as detailed herein. By splitting the band into two segments and aligning one series of resonators for each frequency, a wide passband with a sharply sloped response curve can be achieved. Thus, in one application, the present invention provides a means of filtering the PCS frequency band (which is achieved by placing resonators in different planes of a single dielectric ceramic block), with sharply sloped response curves.

The procedure for splitting the passband as shown in FIG. 6, can be best described with an example. For the Tx signal, filter F01A may be centered at 1865MHz. Another filter in the same block (F01B) can be centered at 1895 MHz. Together, F01A and F01B creates a Tx signal called F01 centered at 1880 MHz which has a desired profile with more sharply sloped sides than previous filter designs (as shown in dashed lines). The same principle can be used for the Rx signal which operates at a higher frequency. For the Rx signal, filter F02A may be centered at 1945 MHz. Another filter in the same block (F02B) may be centered at 1975 MHz. Together, F02A and F02B create an Rx signal called F02 centered at 1960 MHz which has a desired profile with sharply sloped sides (as shown as dashed line). The embodiment shown in FIGs. 4A and 4B can be used to accomplish the desired frequency response (in dashed line), in FIG. 6.

The present invention is not limited, however, to intra-band filtering. For example, a filter can be designed

which is used for a split band application such that the first series of resonators filter out a frequency in one band of the electromagnetic spectrum and the second series of resonators filter out a frequency in another band of the electromagnetic spectrum. More specifically, a filter can be designed for a split band application in which the first series of resonators filter out a frequency in the 900 MHz range and the second series of resonators filter a signal in the 2 GHz range of the electromagnetic spectrum.

The method of fabrication for the present invention will undoubtedly be different from present conventional pressing technology. Incorporating through holes in different planes may require the use of various pins in different axes of the block. Although prototypes can be produced by conventional machining processes, the present invention contemplates large volume production using advanced pressing technology.

Although various embodiments of this invention have been shown and described, it should be understood that various modifications and substitutions, as well as rearrangements and combinations of the preceding embodiments can be made by those skilled in the art, without departing from the novel spirit and scope of this invention.

What is claimed is:

## Claims

1. A ceramic filter including at least one passband for passing a desired frequency response, comprising:
  - 5 a substantially parallelepiped-shaped ceramic filter body having metallized through holes and comprising a block of dielectric material having a top, bottom, and four side surfaces,
  - 10 the through holes including a first series of metallized through holes extending from the top to the bottom surface, defining a first series of resonators, a second series of metallized through holes extending from  
15 a side surface to an opposite side surface, defining a second series of resonators,
  - a metallization layer substantially coating all surfaces of said filter body with the exception that a  
20 portion of the surface surrounding each resonator is unmetallized, and
  - a first and second input-output pad comprising an area of conductive material on one of the side surfaces and  
25 substantially surrounded by an uncoated area to capacitively couple an electrical signal into and out of said filter body.

2. The filter of claim 1, wherein said dielectric block has three input-output pads such that a first pad serves as an input for a transmit signal, a second pad serves as both an output pad for a transmit signal and an input pad for a receiving signal, and a third pad serves as an output pad for a receiving signal, and said first series of resonators passes a transmit signal and said second series of resonators passes a receiving signal defining a duplexer.
- 10 3. The filter of claim 2, wherein said dielectric block includes a third series of resonators to pass a second transmit signal and a fourth series of resonators to pass a second receiving signal, thereby defining a dual duplexer.
- 15 4. The filter of claim 1, wherein said filter is used in a split band application such that the first series of resonators filter out a frequency in one band of the electromagnetic spectrum and the second series of resonators filter out a frequency in another band of the
- 20 electromagnetic spectrum.

5. A ceramic filter including at least one passband for passing a desired frequency response, comprising:

- 5 a substantially parallelepiped-shaped ceramic filter body having metallized through holes, comprising a block of dielectric material having a top, bottom, front, rear, first end and second end surfaces,
- 10 the through holes including a first series of metallized through holes extending from the top to the bottom surfaces, defining a first series of resonators, a second series of through holes having substantially the same diameter as said first series of through holes, extending from said front surface to said back surface,
- 15 said second series of through holes being perpendicular to said first series of through holes and positioned substantially in the interstices of the first series of resonators and extending transversely with relation to the first series of resonators,
- 20 a metallization layer substantially coating all surfaces of said filter body with the exception that a portion of the top and front surfaces surrounding each resonator are unmetallized defining an electrical print
- 25 pattern, and
- 30 a first and second input-output pad on said back surface substantially surrounded by an uncoated area to capacitively couple an electrical signal into and out of said filter body.

6. The filter of claim 5, wherein said first series of resonators are located at a first end of said filter block in a substantially vertical direction extending from said top to said bottom surface of said block and said second series  
5 of resonators are located at a second end of said filter block in a substantially horizontal direction extending from said front surface to said rear surface of said block, said first and said second series of resonators being substantially perpendicular to each other.

10

7. The filter of claim 5, wherein said resonators are coupled to said input-output pads by an edge capacitance.

8. The filter of claim 5, wherein said resonators are  
15 capacitively coupled to said input-output pads with a wraparound structure, including:

a first pair of coupling members which are adjacent to said series of resonators in a horizontal plane;

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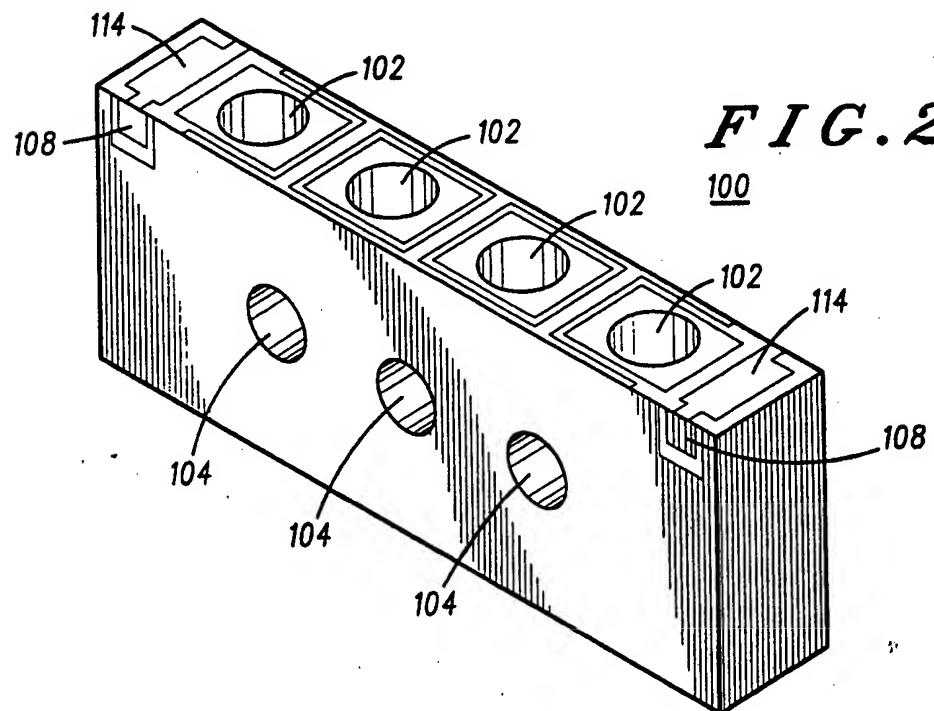
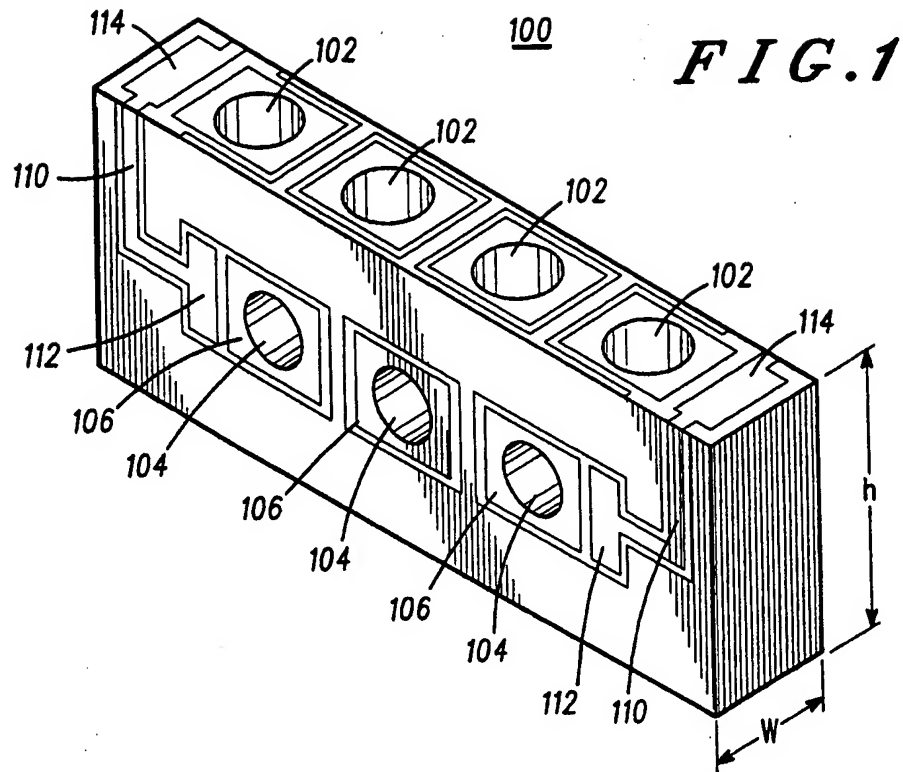
a second pair of coupling members which traverse said top surface of said block adjacent to said series of resonators in a vertical plane; and

25 a conductive transmission line between said first pair of coupling members and said second pair of coupling members.

9. The filter of claim 5, wherein said first series of  
30 resonators are coupled to said input-output pads by a coupling structure which is different from the coupling structure used to couple said second series of resonators.



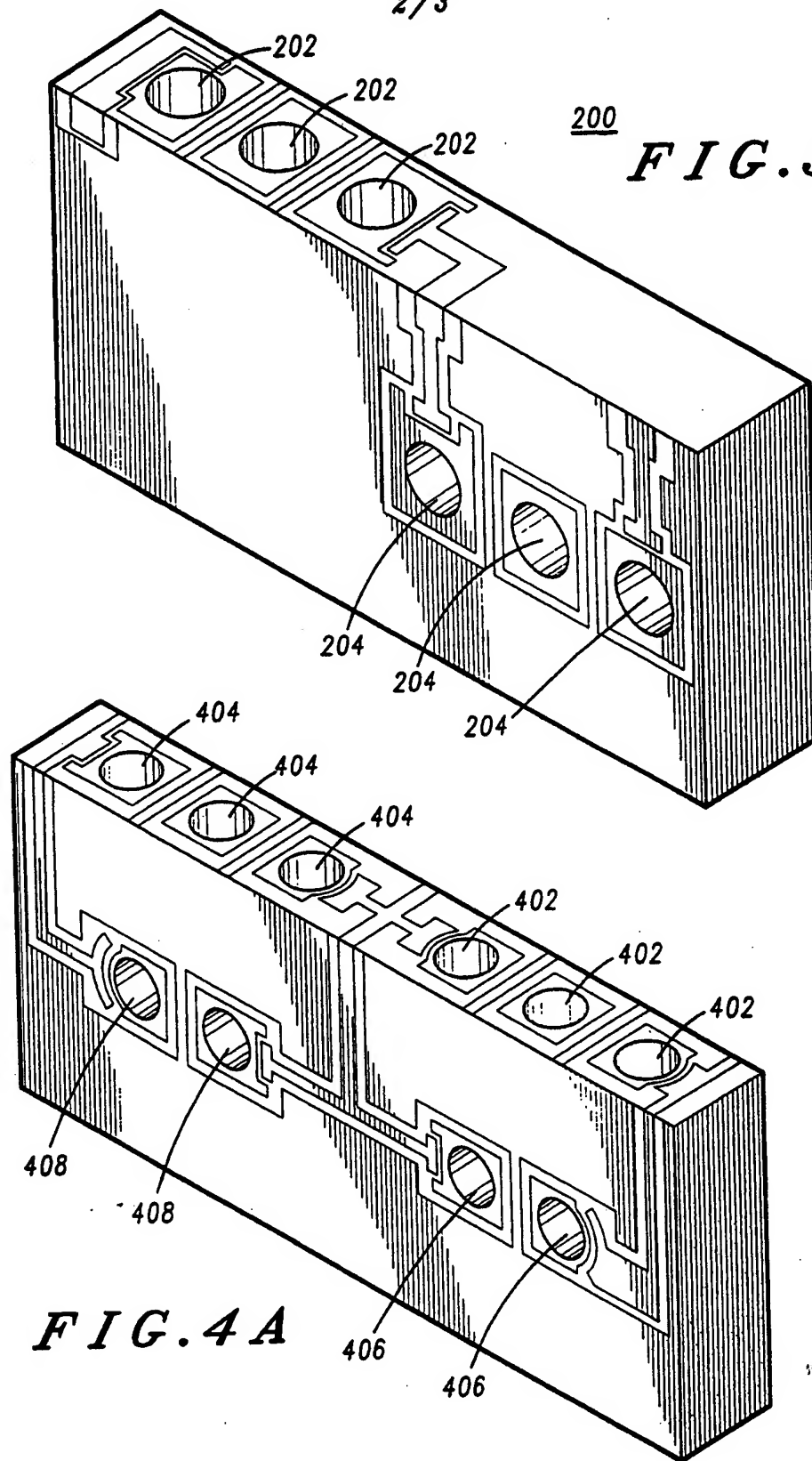
10. The filter of claim 5, wherein a first pair of resonator series pass a transmit signal and a second pair of resonator series pass a receive signal creating a dual duplexer adapted for use in connection with a personal communication services frequency band.
- 5



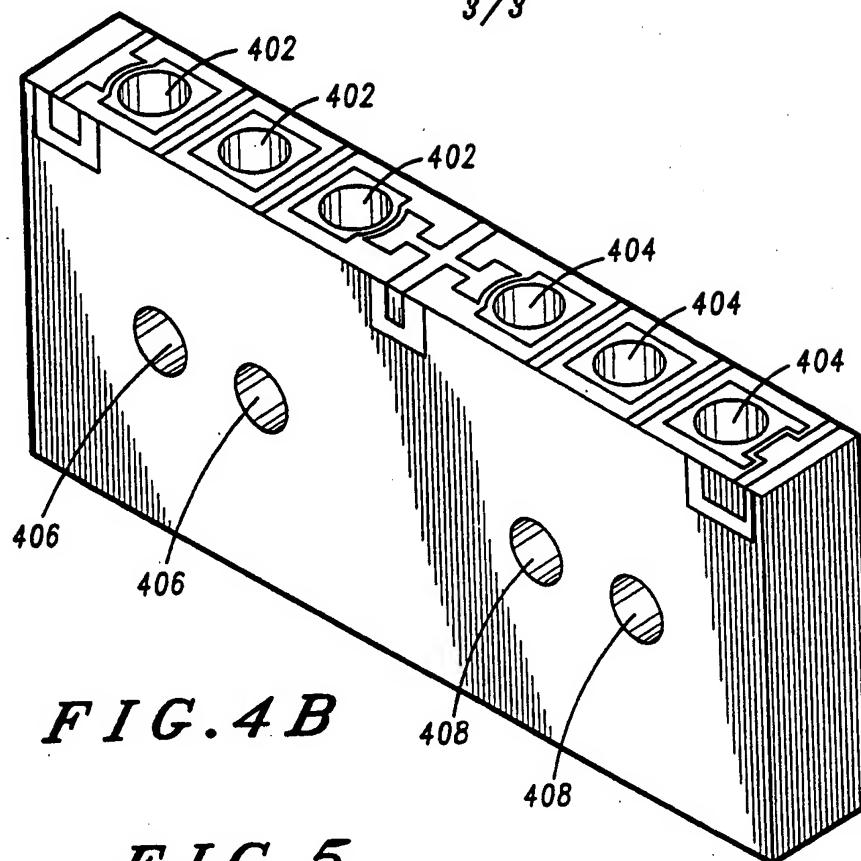
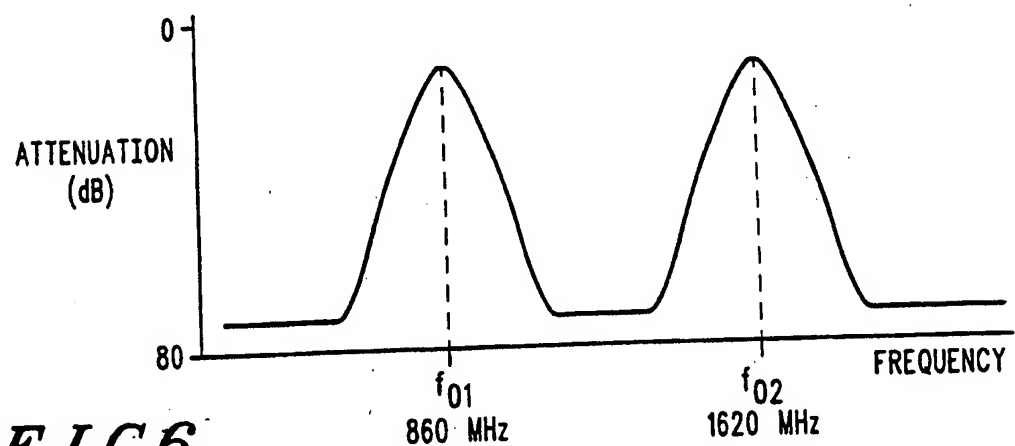
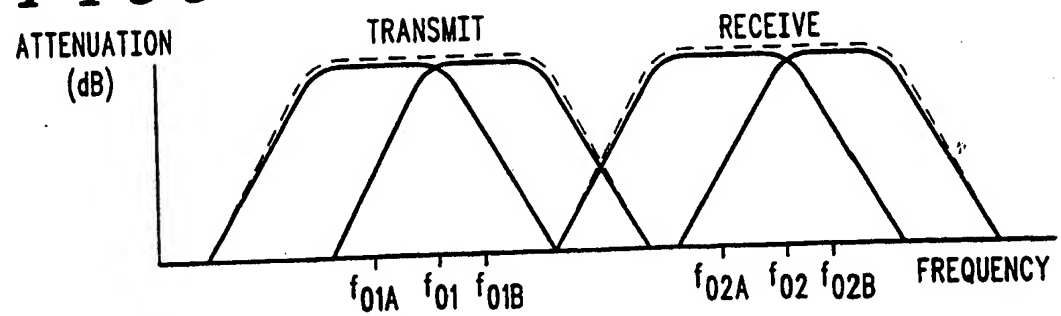
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200

**FIG. 3**



3/3

**FIG. 4B****FIG. 5****FIG. 6**

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/06180

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H01P 1/205  
US CL : 333/ 202, 203, 206, 134  
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 333/ 202, 203, 206, 222, 134

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, A, 5,335,807 (HATTORI) 17 December 1993, see abstract & fig. 1.	1,5,7
Y	US, A, 4,546,333 (FUKASAWA ET AL) 08 October 1985, see figs. 1A,4,11A,11B,13A,13B, & col 1, ls 25-41, col 5, l. 5 - col 6, l. 7, col 7, l. 51 - col 8, l. 17, col 10, ls 25-38, respectively.	1,5,7
A	US, A, 5,012,210 (MARCONI ET AL) 30 April 1991, see figs. 1,4, & col 3, ls 34-66.	1,5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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03 SEPTEMBER 1996

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